Improved Torsional Crystal Viscometry

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Torsionally vibrating piezoelectric crystal transducers offer an elegant way for absolute viscosity measurements. From a metrological point of view there is a particular need for absolute instruments in the field of viscometry as well as for instruments which can be employed over a wide viscosity range from gas to liquid. Torsional crystal viscometers have been used predominantly with liquids while their potential for measurements in gases has not been fully explored.

The paper reports on characteristics which were observed with different unswept crystals in the automated low- and high-temperature instruments of NIST at low fluid viscosities, approaching the dilute gas state, and in vacuum. Transducers with quality factors reaching 1.4·10⁶ have been demonstrated. The real and imaginary components of the admittance were measured at the fundamental crystal resonance in the forced mode of vibration with impedance analyzers to resolve the full resonance curve and not just the determination of the half power bandwidth. The drive voltage was varied between 5 mV and 1.1 V. A transient of the crystal admittance was observed, the duration of which depends on the magnitude of the change in frequency, on the drive voltage, and on the external damping. This transient has to be taken into account when measurements in dilute gases are performed. The influence of the drive voltage on the crystal resonance has also been investigated. Modeling the measured resonance curves in terms of the equivalent electrical circuit of the crystal vibration indicates the occurrence of parasitic nontorsional modes of vibration with increasing drive voltage. Fluid measurements have been carried out with alternative refrigerant R134a. The results will be compared with literature data which have been measured in an oscillating-disk viscometer. The observations of this study suggest that further accuracy gains of measurements with torsional crystal viscometers are possible by measuring the free decay of the crystal vibration. The feasibility of this measurement mode will be discussed.

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